



University  
of Dundee



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# Towards Implementation of Laser Engineered Surface Structures (LESS) for Electron Cloud Mitigation

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# Outline

## 1. Introduction

- Motivation for surface treatment
- SEY and electron clouds
- LESS treatment

## 2. LESS for round beam screens

## 3. LESS for LHC beam screens

## 4. Future for LESS

# LHC beam vacuum system

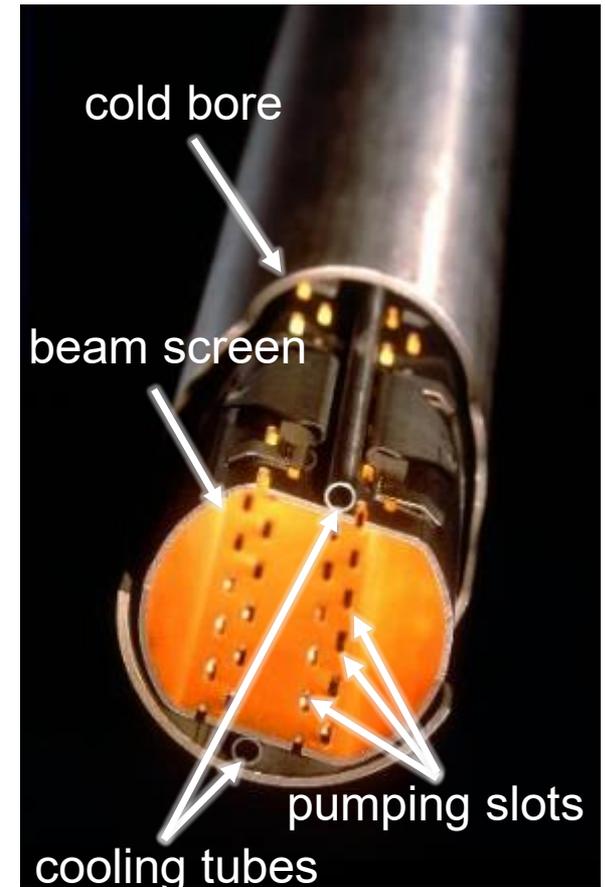
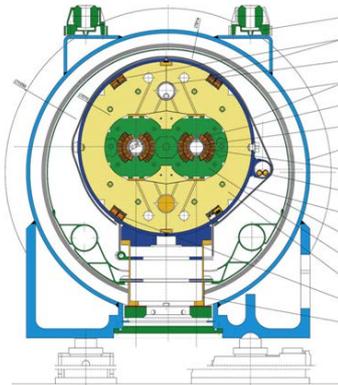
- The largest vacuum system in the world.
- The beam vacuum system consist of 54 km-long pipes (2x LHC circumference).
- Pressure in the order of  $10^{-10} \div 10^{-11}$  mbar - Ultra High Vacuum (UHV) level.
- Low pressure enable accelerating proton/ion beams with low probability of unnecessary collisions with other particles.



# LHC beam screens

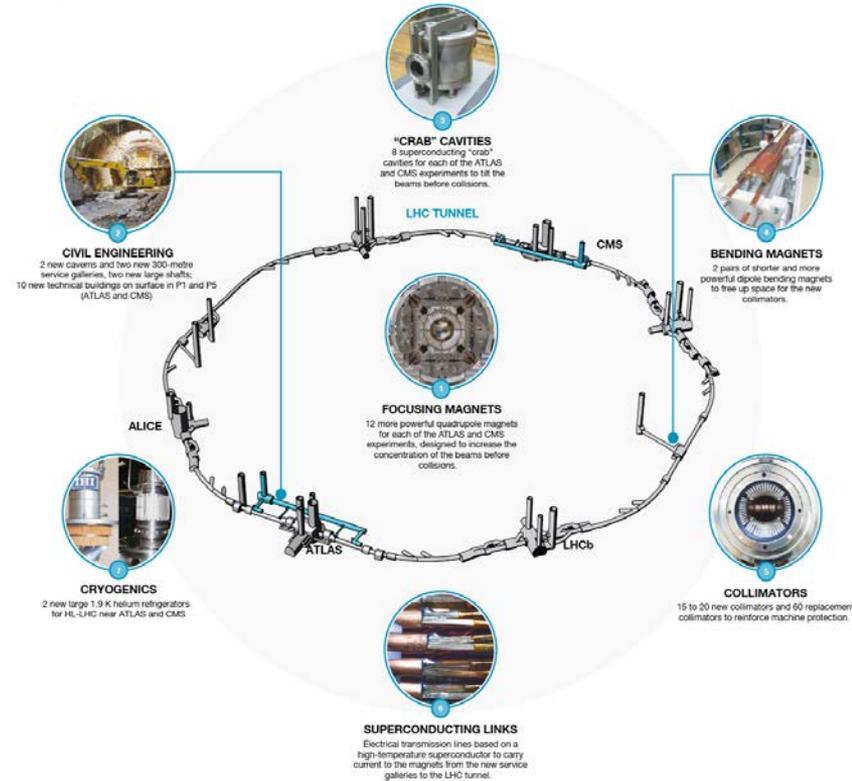
- Designed to intercept beam induced heat loads and ensure vacuum stability.
- Actively cooled (5÷20 K), racetrack-shaped, fitting cold bores of 46 mm to 74 mm diameter.
- Special non-magnetic stainless steel co-laminated with thin copper layer.

LHC DIPOLE : STANDARD CROSS-SECTION



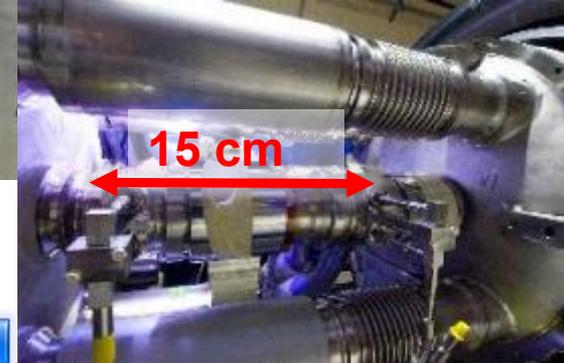
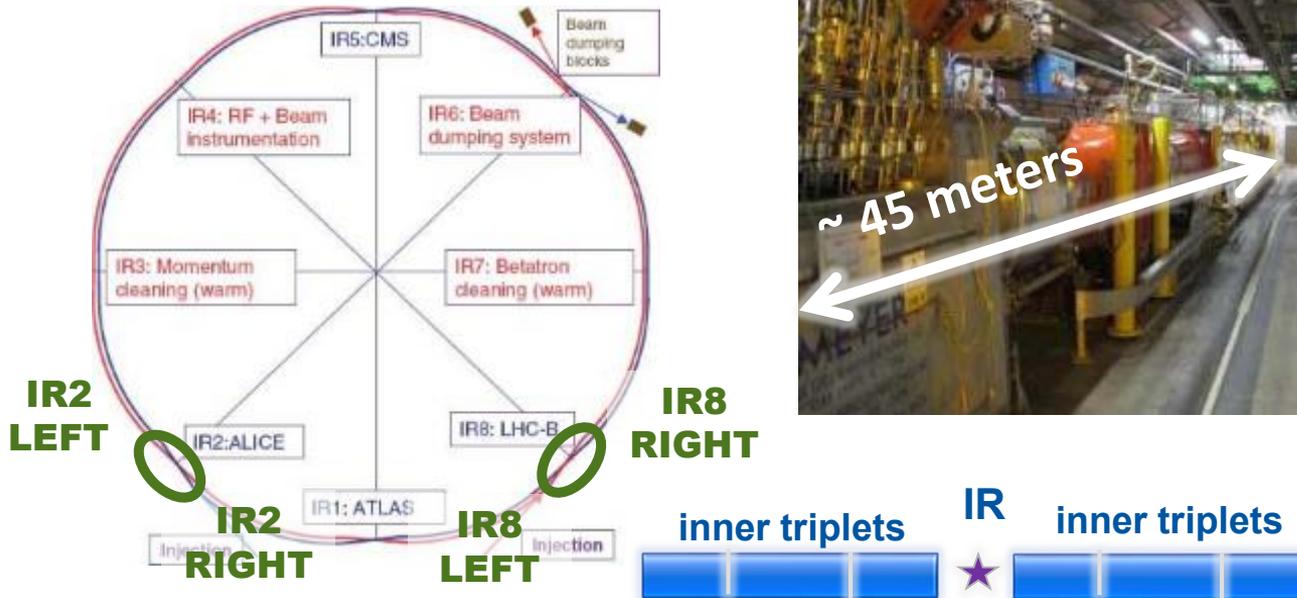
# The High-Luminosity LHC

- HL-LHC aims at increasing luminosity by a factor of 10 beyond the LHC's design value.
- Concern mostly zones around the general-purpose detectors (ATLAS and CMS) but will influence the whole LHC.
- Beam generated heat loads (like electron cloud) will especially affect experimental areas that will not be upgraded (LHCb and ALICE).

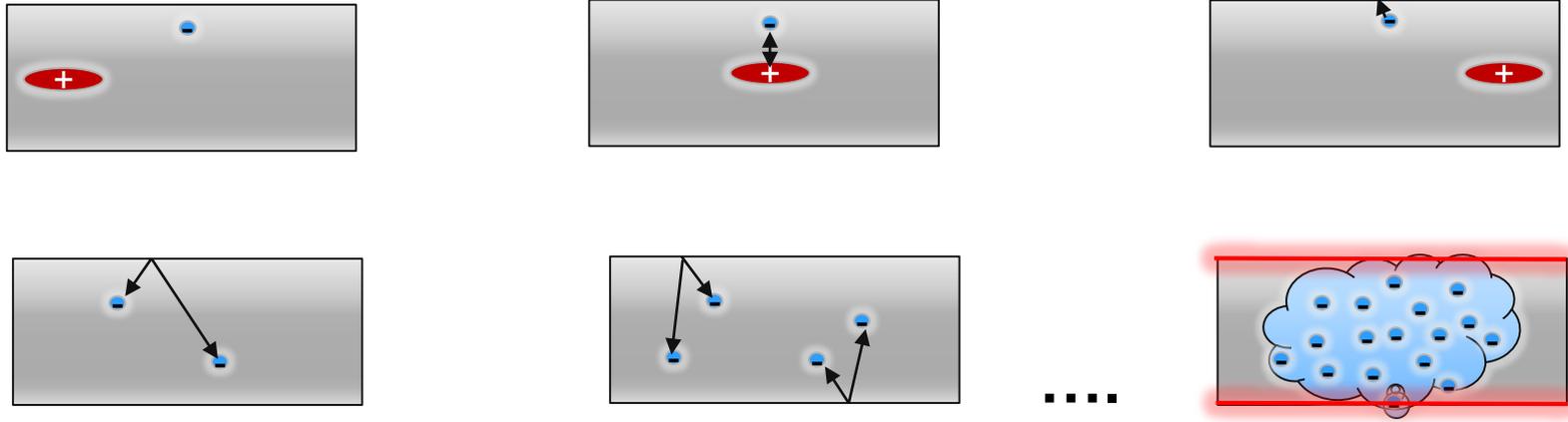


# In-situ treatment of inner triplet magnets

- In order to reduce heat load on inner triplet magnets, the in-situ treatment is foreseen during **Long Shut-down 3**.



# Secondary emission, electron multipacting and heat loads

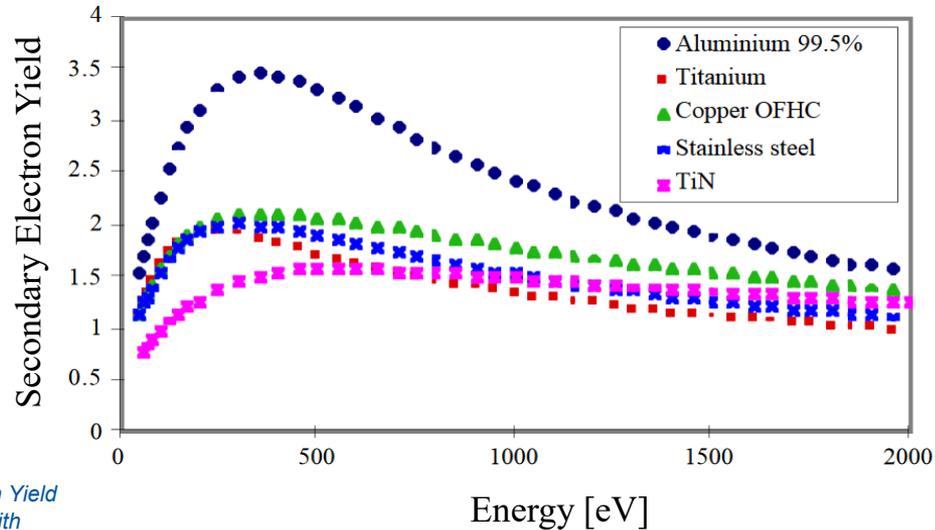


Increased heat load on the beam screens and to cryogenic system



# Secondary Electron Yield

$$SEY = \frac{\text{no. of secondary electrons emitted}}{\text{primary electron hitting surface}}$$

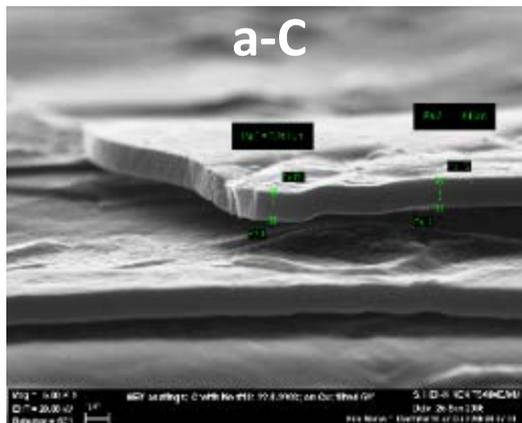


V. Baglin et al. "The Secondary Electron Yield of Technical Materials and its Variation with Surface Treatments"

# How to reduce electron cloud?

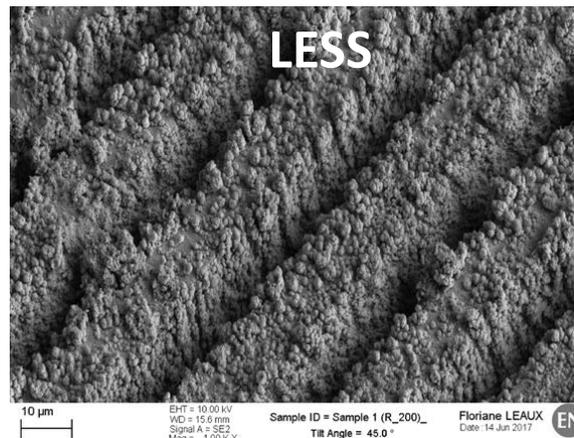
Modification of electronic properties of the surface

## AMORPHOUS CARBON COATING



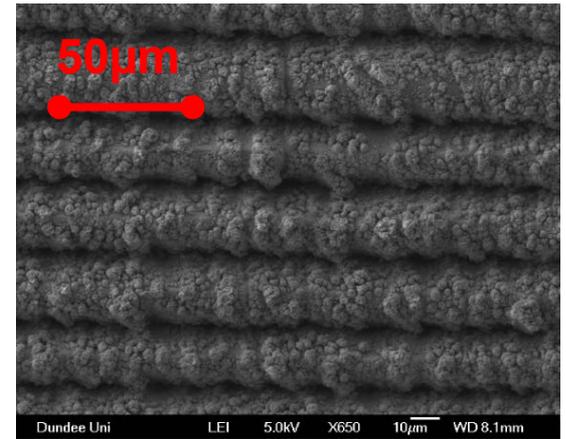
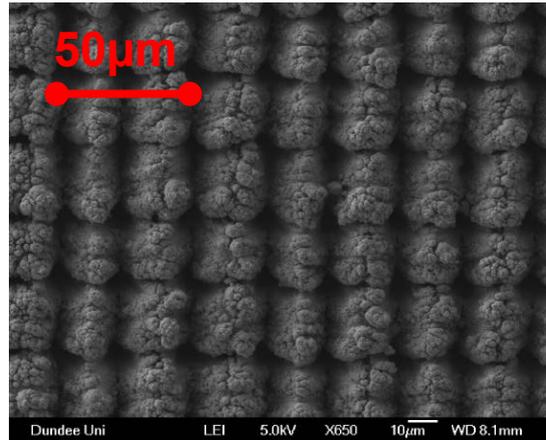
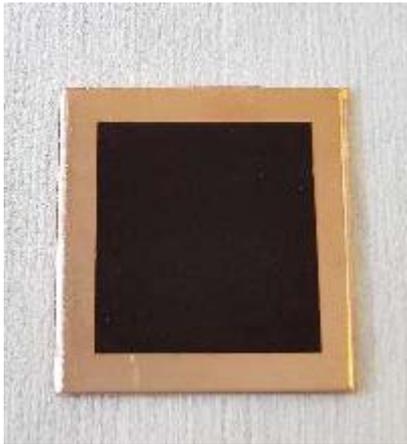
Modification of morphological properties of the surface

## LASER ENGINEERED SURFACE STRUCTURES



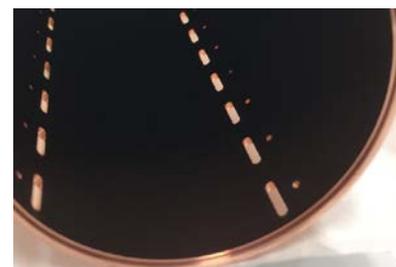
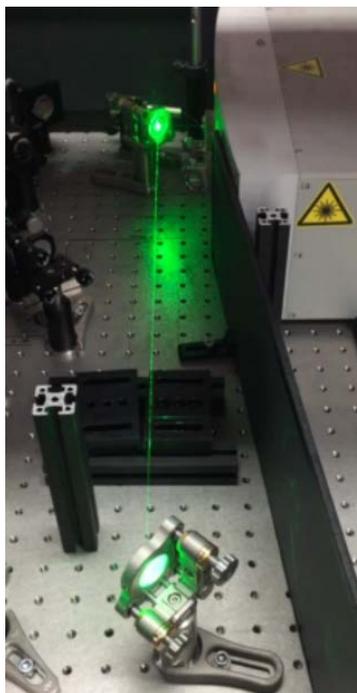
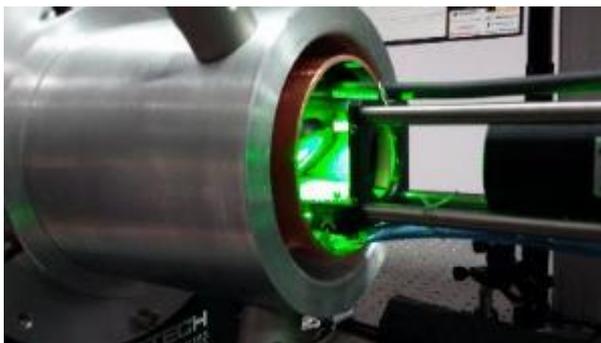
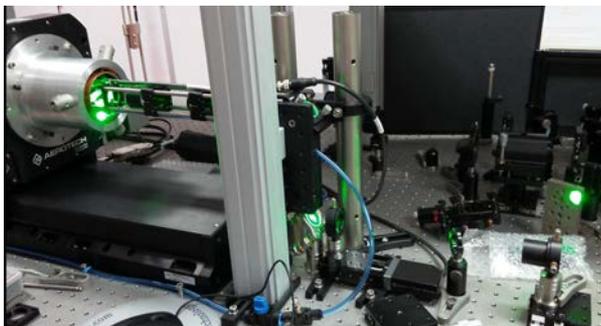
# Laser Engineered Surface Structures (LESS)

Copper surface modified by laser ablation. Surface morphology ( $\rightarrow$  **SEY**<1.0) depends on chosen laser parameters.



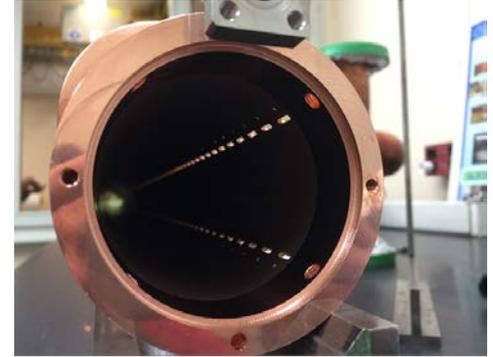
# LESS treatment of segmented COLDEX beam screen

January-February 2017



# COLDEX beam screen assembly at CERN-SPS

March 2017



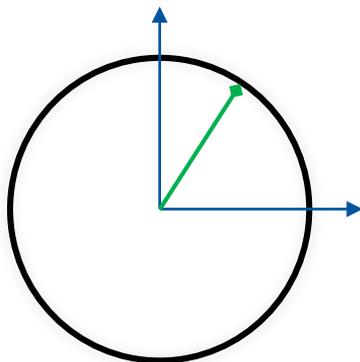
**No electron cloud observed  
!!!**

**Poster:** R. Salemme et al. "First Beam Test of Laser Engineered Surface Structures (LESS) at Cryogenic Temperature In CERN SPS Accelerator" WEPMG005, 02 May 2018

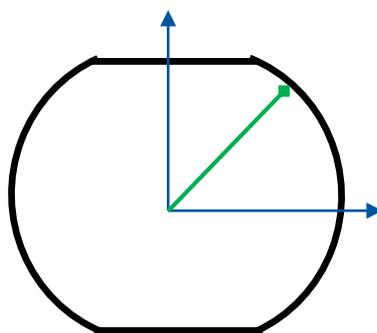
# Challenges of LHC beam screens treatment

## Laser focus point

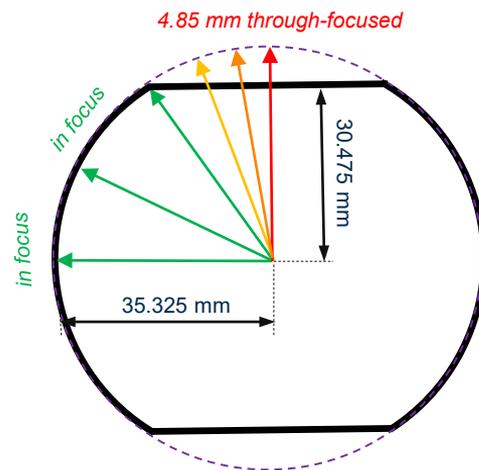
COLDEX beam screen



LHC beam screen

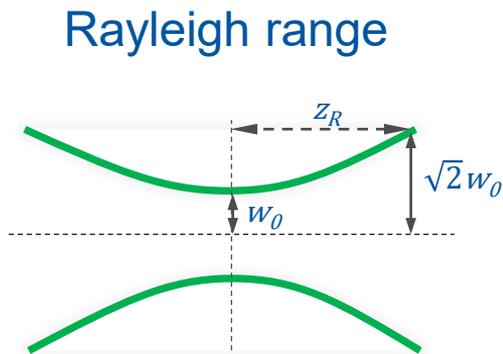
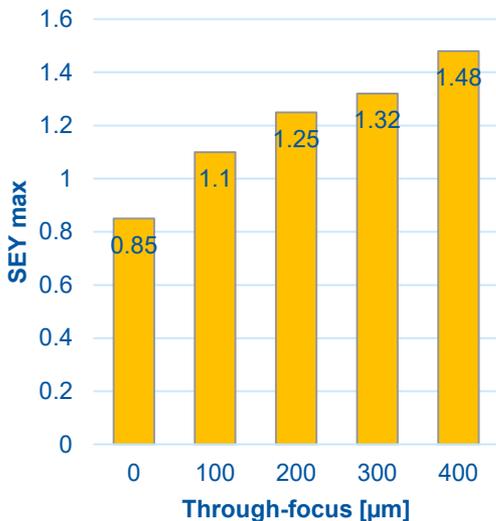


Type 74 LHC beam screen



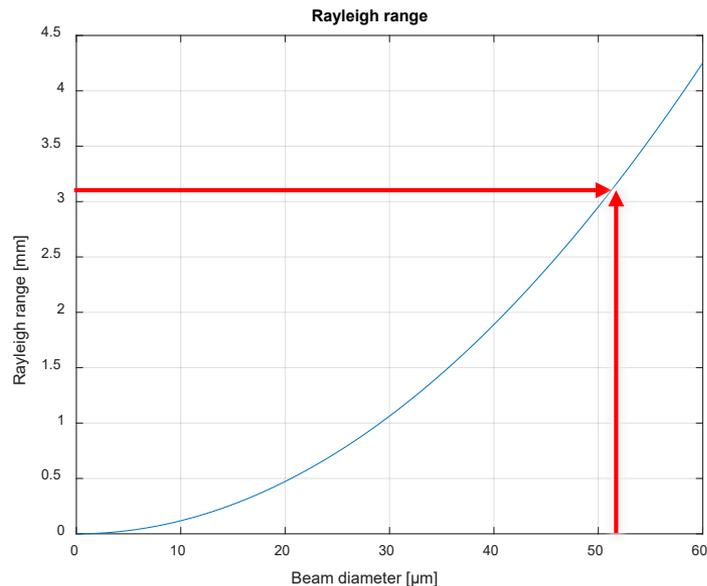
# Challenges of LHC beam screens treatment

## Laser focus point



$$w(z) = w_0 \sqrt{1 + \left(\frac{z}{z_R}\right)^2}$$

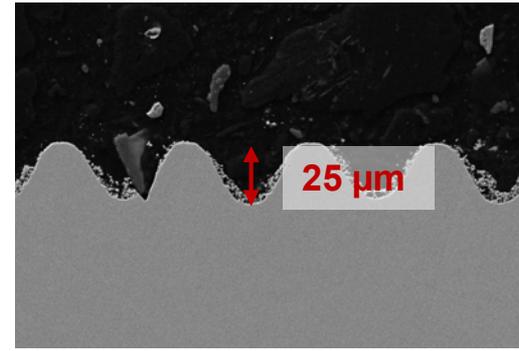
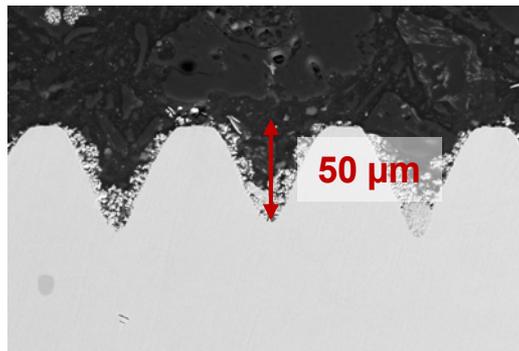
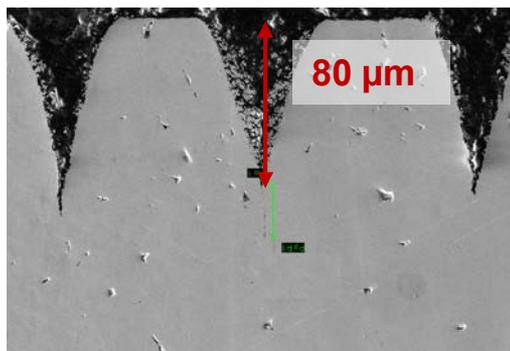
$$z_R = \frac{\pi \omega_0^2}{\lambda M^2}$$



# Challenges of LHC beam screens treatment

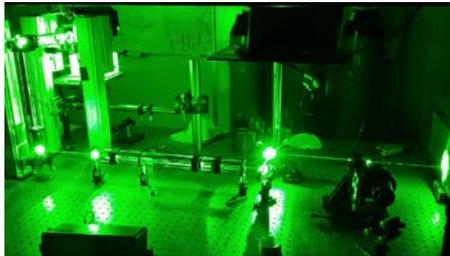
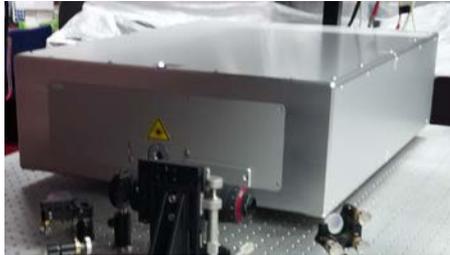


- Treatment depth  
Depends on:
- Spot size
  - Repetition rate
  - Pulses per spot
  - Hatch distance

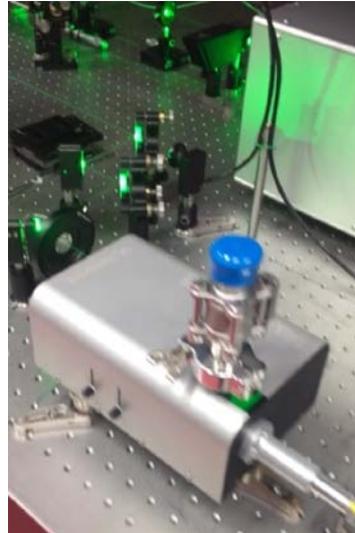


# Components of the LESS treatment system

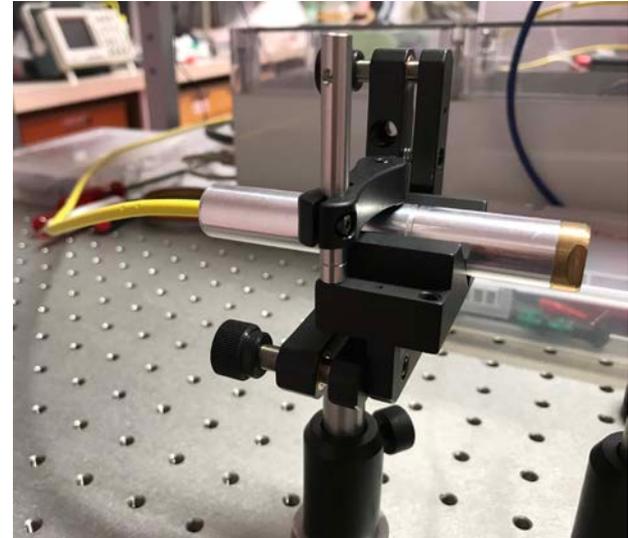
532 nm wavelength laser



Beam delivery system

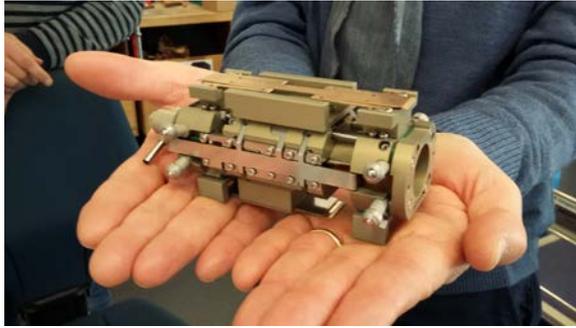


Fibre and fibre head

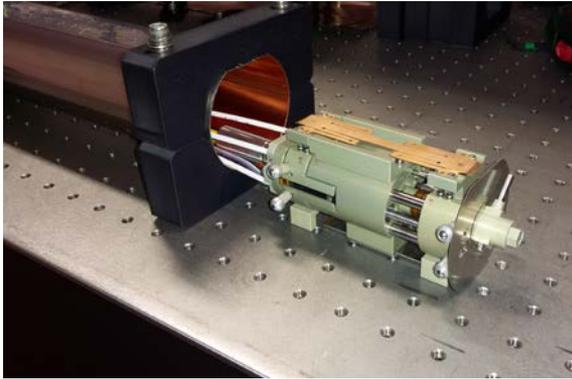


# LESS inchworm robot

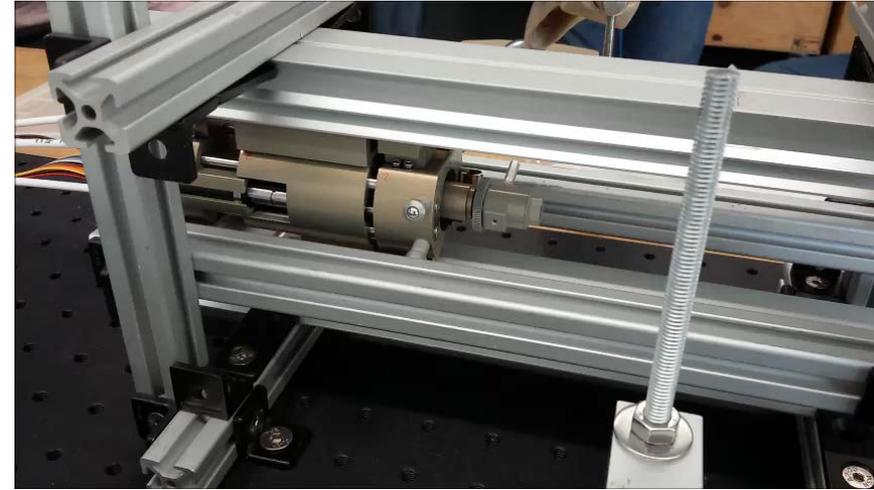
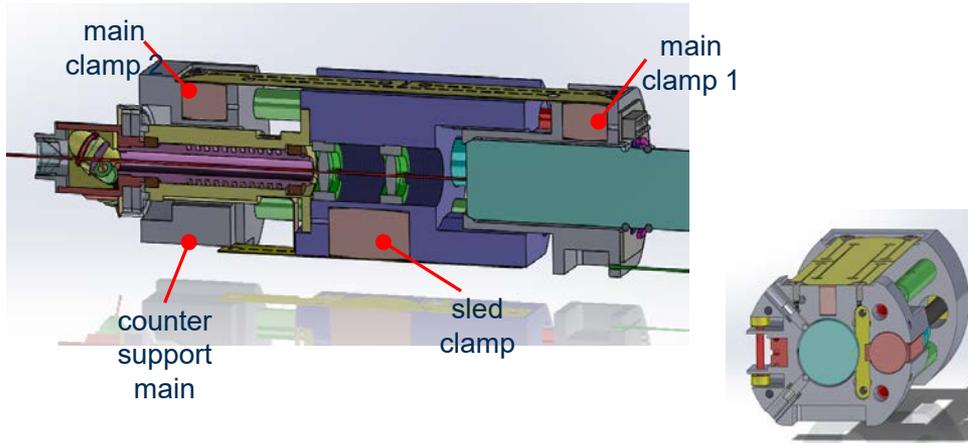
January 2018



General Electric  
Inspection Robotics

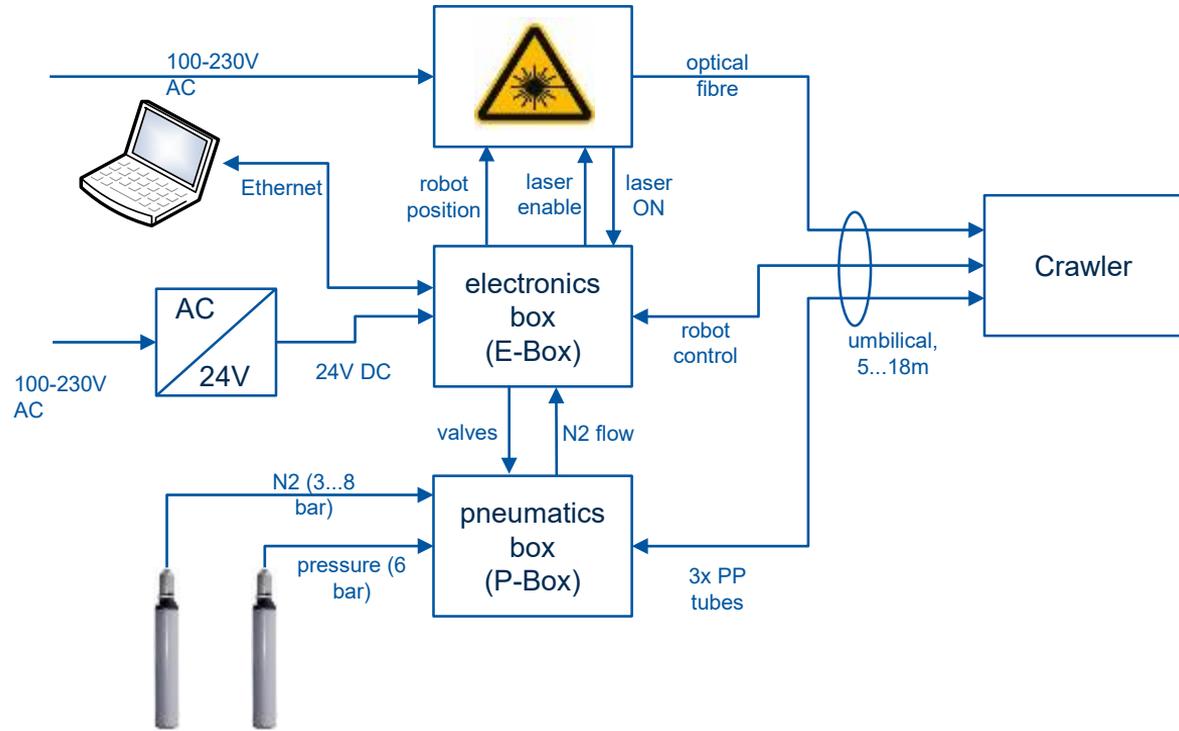


# LESS inchworm robot



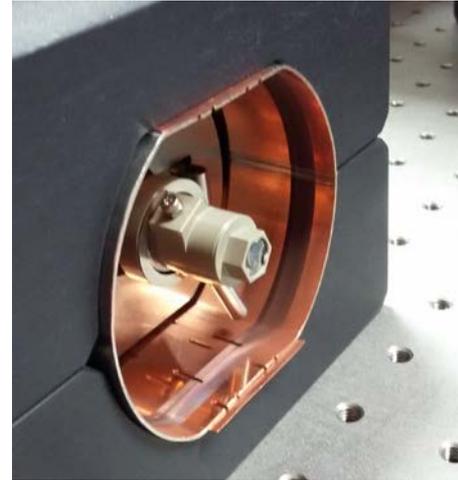
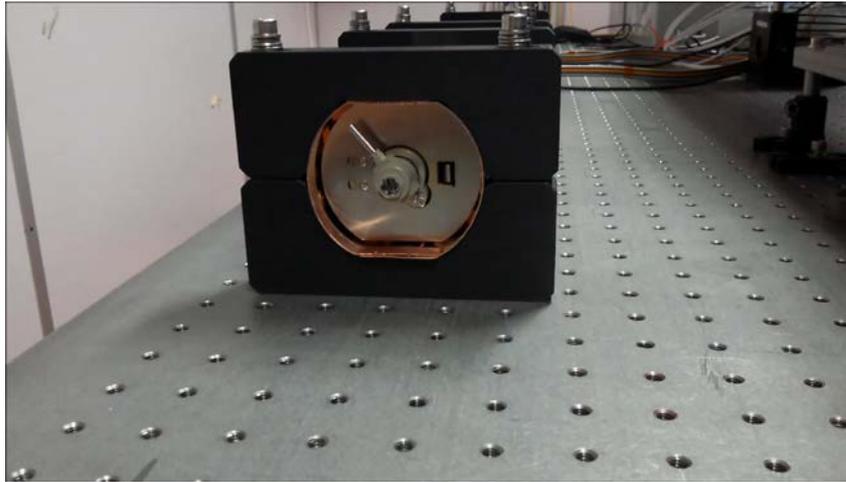
- ✓ Crawling movement along the beam screen by means of pneumatic clamps
- ✓ Precise longitudinal movement during treatment using feed screw
- ✓ Rotational movement of the laser head

# Integrated control of LESS treatment system



# First treatment inside the LHC beam screen

February 2018



# Next steps in LESS development

- Surface impedance measurements
- Ion and electron stimulated desorption
- Dust mitigation
- Treatment of long ( $> 10$  meters) beam screens

# Acknowledgements



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